Description

Device and method for identifying defects in a fuel injection system

The invention relates to a device for identifying defects in a fuel injection system in which the fuel injection system includes at least one high-pressure pump, at least one fuel accumulator, at least one fuel pressure control valve and at least one pressure sensor for recording the pressure prevailing in at least one fuel accumulator.

Furthermore, the invention also relates to a method for identifying defects in a fuel injection system, with the fuel injection system including at least one high-pressure pump, at least one fuel accumulator, at least one fuel pressure control valve and at least one pressure sensor for recording the pressure prevailing in at least one fuel accumulator.

In addition, the invention relates to a vehicle with a device for identifying defects in a fuel injection system as well as a diagnostic unit with a device for identifying defects in a fuel injection system.

Fuel injection systems which are within the framework of this publication are used for the high-pressure injection of fuel into the cylinders of an internal combustion engine.

Such a fuel injection system may be equipped with a fuel accumulator which is filled with fuel using a high-pressure pump and is in this case brought to a pressure level required for the high-pressure injection. Fuel is fed to the high-pressure pump itself using a low-pressure fuel pump; said fuel drawn out of a fuel tank using a low-pressure fuel pump. Different measures can be taken in order to control or regulate the fuel injection system. Both mechanical regulators in the

low-pressure area and control valves in the high-pressure area are known.

The latter is, in particular, of importance in connection with continuously operating high-pressure fuel pumps which feed the fuel into the fuel accumulator (the "rail"). Such fuel pressure control valves can be adjusted via a magnetic force which can be specified electrically.

Therefore, by and large, complex systems are involved here in which different defects may occur. The fact that there is a defect can be seen in particular in a lower fuel pressure in the fuel accumulator - however, it is not possible to exactly locate the cause of defects only on the basis of this pressure which has been identified as being too low.

It is the object of the invention to further develop the devices and methods of the prior art in such a way that the problems described are solved, in which case, in particular, the source of the defect will be located in a cost-effective manner.

This object of the invention is achieved by the features of the independent claims.

Advantageous embodiments and further developments of the invention are obtained from the dependent claims.

The invention is based on the generic device in that the occurrence of at least one defect in the fuel injection system can be identified by recording a pressure in the fuel accumulator which is too low and that a high-frequency component of a first signal characterizing the pressure course in the fuel accumulator over time can be used in order to isolate the source of the defect. The high-frequency component of the fuel pressure course in the fuel accumulator over time

correlates with the possible source of the defects. Therefore, by filtering out said high-frequency component it can be indicated with a high probability that the source of the defects be determined, so that should there be a defect on repairing the fuel injection systems, the components can specifically be exchanged or repaired.

The device according to the invention can in a particularly advantageous way be developed further by applying lowpass filtering to the first signal so that a lowpass-filtered second signal can be generated, that a third signal can be generated as the absolute difference between the first signal and the second signal and that the third signal can be compared with a predefined threshold value in which case, depending on the comparison, the source of the defect can be isolated. Therefore, the pressure course over time is then first of all lowpass-filtered. By forming the difference and its absolute value between this lowpass-filtered signal and the original signal, an additional third signal is obtained whose amplitude has an absolute validity so that this can be compared with a predefined threshold value.

It is particularly advantageous that it is possible to conclude that there is a defect in at least one high-pressure pump if the third signal essentially, particularly under a high load, exceeds the predefined threshold value. Because in the case of a defect of the high-pressure pump, particularly under a high load, there are in general strong high-frequency components in the pressure course in the fuel accumulator over time, it is possible in the case of suitably predefined threshold values to conclude that there is a defect in the high-pressure pump if the third signal exceeds this threshold value.

On the other hand, it is particularly advantageous for the invention that it is possible to conclude that there is a

defect in at least one fuel pressure control valve if the third signal is essentially below the predefined threshold value. The pressure loss in the rail, in the case of high-frequency components with low amplitude, most probably has its origin in other components in the high-pressure cycle, i.e. most probably in a defective fuel pressure control valve.

In connection with the device according to the invention it is particularly advantageous that the pressure determined in at least one fuel accumulator can be evaluated for plausibility on the basis of a value measured by a lambda probe arranged in the exhaust gas flow of an internal combustion engine assigned to a fuel injection pump and that it is possible to conclude that there is a defect in at least one pressure sensor if the plausibility check is negative. Therefore, as soon as the fuel pressure sensor records that the pressure or the pressure in the fuel accumulator present in the low-pressure area of the fuel injection system is too low, a test is then carried out by means of a cross-plausibility check by including the information supplied by the lambda probe to determine whether or not the fuel pressure sensor is defective. The background to this is that a strong pressure loss in the fuel accumulator has a direct influence on the mixture formation and, therefore, on the exhaust gas values determined by the lambda probe. Therefore, in the case of exhaust gas values within predefined boundaries and a pressure loss reported nevertheless in the rail it can be highly probable that the fuel sensor is defective and in particular has a mechanical defect.

In addition, provision can be made in an advantageous manner for the pressure determined in at least one fuel accumulator to be able to be compared with a desired pressure or a pressure that is actually present in a low-pressure area of the fuel injection system and it is possible to conclude that that there

is a defect in the low-pressure area if the pressure determined in at least one fuel accumulator is lower than the desired pressure, or it is possible to conclude that there is a defect in the drive of the high-pressure pump if the pressure determined in at least one fuel accumulator is lower than the pressure that is actually present in the low-pressure area. If the pressure in the fuel accumulator is lower than the pressure in the low-pressure area available at the same point in time, there is a high probability that this is due to the fact that the drive of the high-pressure pump is defective. However, in this case the high-pressure pump equipped with a membrane actually functions as a throttle so that there is a lower pressure on the outlet side of the high-pressure pump than on the inlet side of said pump. However, it is likewise recommended to also carry out a comparison of the pressure determined in the fuel accumulator with the desired pressure in the low-pressure area. Particularly in the case of a pressure in the fuel accumulator which is considerably lower than the desired pressure in the low-pressure area, it is probable that there is a defect in the low-pressure area.

The device according to the invention is developed further in a very advantageous manner in that at least one electronic control unit allocated to the fuel injection system is provided in which at least one of the said evaluations can be performed. In particular, the different threshold value comparisons as well as filtering and the formation of differences can take place on a digital basis in the electronic control unit of the fuel injection system. However, it is also feasible, on the other hand, that parts of the evaluation can be implemented by analog switching methods. In addition, parts of the said evaluations can be carried out in other control units of a motor vehicle or another device in which case communication via a data bus is in particular possible between these components

and the control of the fuel injection system.

Usefully, the device is embodied in such a way that it features an interface enabling it to be installed into a motor vehicle. Therefore, the identification of defects can be carried out in the motor vehicle itself. Identified defects can be stored in a defect memory.

However additional or alternative provision can be made for the device to feature an interface so that it can be installed in a diagnostic unit; said unit being separate from the motor vehicle. Therefore, the device can also be used in a workshop within the framework of vehicle diagnostics.

The invention is furthermore based on the generic method in that the method includes the steps: Identifying the occurrence of at least one defect in the fuel injection system by recording a pressure in the fuel accumulator which is too low and using a high-frequency component of a first signal characterizing the pressure course in the fuel accumulator over time in order to isolate the source of the defect. In this way, the advantages and particulars of the device according to the invention are also converted within the framework of a method. This also applies to the particularly advantageous embodiments of the method according to the invention given below.

The method according to the invention can in a particularly advantageous way be developed further in that the first signal is lowpass-filtered so that a lowpass-filtered second signal is generated, that a third signal is generated as the absolute difference between the first signal and the second signal and that the third signal is compared with a predefined threshold value in which case, depending on the comparison, the source of the defect is isolated.

It is particularly advantageous that it is concluded that there is a defect in at least one high-pressure pump if the third signal, essentially exceeds the predefined threshold value, particularly under a high load exceeding.

On the other hand, the invention is particularly useful in that it is concluded that there is a defect in at least one fuel pressure control valve if the third signal is essentially below the predefined threshold value.

In connection with the method according to the invention it is particularly advantageous that the pressure determined in at least one fuel accumulator is evaluated for plausibility on the basis of a value measured by a lambda probe arranged in the exhaust gas flow of an internal combustion engine assigned to a fuel injection pump and that it is concluded that there is a defect in at least one pressure sensor if the plausibility check is negative.

In addition, provision can be made in an advantageous manner for the pressure determined in at least one fuel accumulator to be compared with a desired pressure or with a pressure that is actually present in a low-pressure area of the fuel injection system and for it to be concluded that that there is a defect in the low-pressure area if the pressure determined in at least one fuel accumulator is lower than the desired pressure, or for it to be concluded that there is a defect in the drive of the high-pressure pump if the pressure determined in at least one fuel accumulator is lower than the pressure that is actually present in the low-pressure area.

The method according to the invention is developed further in a very useful manner by the fact that at least one electronic control unit allocated to the fuel injection system is provided in which at least one of the said evaluations takes place.

Usefully, the method is embodied in such a way that the pressure determined in at least one fuel accumulator is compared with the desired pressure or the pressure that is actually present in the low-pressure area of the fuel injection system before the high-frequency component of the first signal is included. This means that first of all it can be established or excluded whether the low pressure reported in the high-pressure accumulator has its origin in a defective high-pressure pump drive or a defective low-pressure area. Only then is it necessary to carry out the other diagnostic steps.

In addition or as an alternative provision can also be made for the plausibility evaluation for determining the functional integrity of the pressure sensor to be carried out before the pressure determined in at least one fuel accumulator is compared with a desired pressure or the pressure that is actually present in a low-pressure area of the fuel injection system. Therefore, it can first of all be established whether or not there is a defect in the low-pressure area with regard to the drive of the high-pressure pump. Only then is it necessary for the evaluation to be carried out on the basis of the high-frequency components of the pressure course in the fuel accumulator.

In addition, the invention relates to a motor vehicle with a device according to the invention or for carrying out a method according to the invention.

The invention also relates to a diagnostic unit with a device according to the invention or in order to carry out a method according to the invention respectively.

The invention is based on the knowledge that a far-reaching diagnosis of a fuel injection system can be undertaken on the basis of measured values which are available at any time. It

is, in particular, possible to conclude that there is either a mechanical defect in the high-pressure pump or a mechanical defect in the fuel pressure control valve on the basis of the high-frequency components of the pressure course in the fuel accumulator. Therefore, in case of defects it is possible to specifically exchange or repair the defective components without the requirement of having to take further diagnostic steps.

The invention is described in more detail with reference to the enclosed drawings and on the basis of the preferred embodiments.

The Figures show:

Figure 1 a schematic diagram of a fuel injection system;

Figure 2 a schematic cross-sectional diagram of a fuel pressure control valve;

Figure 3 two diagrams in order to explain the filtering used within the framework of the invention;

Figure 4 a measurement diagram which is characteristic of a defect in the fuel pressure control valve;

Figure 5 a measurement diagram which is characteristic of a defect in the high-pressure pump; and

Figure 6 a flowchart to explain a method according to the invention.

Figure 1 shows a schematic diagram of a fuel injection system. Fuel is fed from a fuel tank 20 via a fuel line 22 using a low-pressure pump 24. The low-pressure pump 24 supplies fuel to a low-pressure cycle 26. The pressure in this low-pressure cycle 26 is adjusted by using a mechanical low-pressure control

device 28 which is in the position to return the fuel to the fuel tank 20 via a fuel line 30. The fuel reaches a high-pressure pump 10 from the low-pressure pump 24 via the low-pressure cycle 26 with a basic admission pressure. This high-pressure pump 10 feeds the fuel in a high-pressure cycle 32 and particularly in a fuel accumulator 12. The fuel accumulator 12 is equipped with injectors or injection valves 34, 36, 38, 40 which can inject the fuel into the cylinder chamber. Because the high-pressure pump 22 operates continuously, a desired pressure adjustment must be provided elsewhere in the fuel accumulator 12. This takes place by means of a fuel pressure control valve 14 via which the difference between the fuel fed by the high-pressure pump 12 and the fuel in the low-pressure cycle 26 injected into the cylinders by the injection valves flows off in the low-pressure cycle 26. The fuel pressure control valve 14 described in greater detail in connection with Figure 2 is activated by an electronic control 18 which (in addition to others) as an input value receives a value determined by a pressure sensor 16 arranged on the fuel accumulator 12. Therefore, the injection pressure can be regulated due to the fact that the fuel pressure control valve 14 more or less allows fuel to flow into the low-pressure cycle 26, depending on the activation by the electronic control 18.

Figure 2 shows a schematic cross-sectional diagram of a fuel pressure control valve. The fuel pressure control valve 14 includes a magnetic coil (not shown) which exerts a force onto an armature 42. The armature 42 is connected permanently to a valve tappet 44 which depending on the position of the armature 42 more or less creates an opening 46 to the low-pressure cycle 26. Therefore, depending on the flow of current through the magnetic coil, it is possible that on the basis of the magnetic force and the counterforce of the inrushing fuel from the high-pressure cycle 32 onto the valve tappet 44, an equilibrium is

obtained depending on the flow of current through the magnetic coil. The magnetic force is preferably generated by a pulse-width modulated voltage, so that the basic pulse duty ratio of the coil voltage represents the basis for adjusting the pressure in the fuel accumulator 12. In this case, a linear characteristic between the hydraulic force and the magnetic force is especially implemented.

Figure 3 shows two diagrams which explain the filtering used within the framework of the invention. In the top diagram, the fuel pressure is plotted against time. The line p_K symbolizes the course of pressure in the fuel accumulator. The line p_{KF} symbolizes a lowpass-filtered course of pressure in the fuel accumulator. This lowpass-filtering is preferably undertaken in the electronic control 18, but can also be carried out by other well-known ways and means. The difference Δ is formed between the two curves p_K and p_{KF}. The absolute values of this difference Δ are again shown in the bottom diagram in Figure 3.

By means of this filtering and the formation of differences it is thus possible to obtain a value curve which can be compared with an absolutely selected pressure threshold so that in this way the high-frequency component of the fuel pressure course can be used as criterion for the ratios in the fuel injection system.

Figure 4 shows a measurement diagram which is characteristic of a defect in the fuel pressure control valve. The fact that there is a defect in the fuel injection system can be established by means of the fact that the fuel pressure p_K in the fuel accumulator is only around 7000 hPa. As a result, low pressure dominates in the rail. However, on the basis of this information alone, it has not yet been indicated whether or not the fault is in the area of the high-pressure pump or in the area of the fuel pressure control valve. This indication is

only obtained on the basis of the evaluation described in connection with Figure 3. By means of the described consecutive lowpass-filtering and formation of differences, a signal curve Δ reflecting the high-frequency component of the fuel pressure course can be obtained. In the present example according to Figure 4, this high-frequency component Δ is very small and this means that, in the case of a suitably selected threshold value, it is below the said threshold value. This applies both to a high rotational speed and a low rotational speed which is drawn in the diagram in Figure 4 as a curve N because a defect, in particular mechanical, in the fuel pressure control valve is mainly independent of the load.

Figure 5 shows a measurement diagram which is characteristic of a defect in the high-pressure pump. The fuel pressure curve p_K shown here has a strong high-frequency component. By means of the filtering method and the formation of differences method described in connection with Figure 3, the signal curve Δ characterizing the signal of the high-frequency component is filtered out. With a suitably selected threshold value, large parts of this signal curve Δ will be above this threshold value. This makes it possible to conclude that there is a defect in the high-pressure pump, because in particular after the membrane of the high-pressure pump has been torn, considerable high-frequency oscillations are superposed on the fuel pressure signal. In addition, in the diagram according to Figure 5 it can be identified that the signal Δ is essentially only under a high load above a suitably selected threshold value so that this can be used as a further decision-making criterion for fault tracing.

Figure 6 shows a flowchart which explains a method according to the invention. If it is identified in step S10 that there is a lower pressure in the fuel accumulator, i.e. a low pressure, a

cross-plausibility check is then first of all carried out in step S12 between the fuel pressure determined by the pressure sensor and one or several lambda probe values. If it is determined that the lower pressure value is not reflected in the values determined by the lambda probe, it is then concluded according to step S14 that there is a defect in the pressure sensor. However, if there is plausible behavior with regard to the pressure sensor and the lambda probe, then it is determined in step S16 whether or not the fuel pressure in the fuel accumulator is lower than the pressure in the low-pressure cycle. If it is, then it is possible to conclude that there is a defect in the pump drive of the high-pressure pump according to step S18 because the high-pressure pump which is not driven acts as a throttle. Likewise, it could also still be possible to test whether or not the fuel pressure in the rail is lower than a desired pressure in the low-pressure cycle and in this way to conclude that there possibly is a defect in the low-pressure cycle. If it is not determined that there is a defect in the drive in the high-pressure pump, then in step S20 the method switching off the high-frequency component and described on the basis of Figure 3 and shown in connection with Figure 4 and Figure 5 is carried out. Therefore, the absolute value of the difference between the fuel pressure and the lowpass-filtered fuel pressure is compared with a defect threshold value and then particularly under a high load. If this absolute value determined is lower than the defect threshold value then there is a high probability that there is a defect in the fuel pressure control valve according to step S22. On the other hand, i.e. if the defect threshold value is exceeded there is a defect in the high-pressure pump according to step S24.

The invention can be summarized as follows: The invention makes the identification of defects possible in a fuel injection system comprising a fuel accumulator 12, a continuously

operating high-pressure pump 10 and a fuel pressure control valve 14. By evaluating the high-frequency component of the fuel pressure course in the fuel accumulator 12, it is possible to indicate with a high probability which of the components are defective, with this being supported especially by additional evaluations performed within a diagnostic procedure.

The features of the invention published in this description, in the drawings as well as in the claims can be of significance both individually and in any combination for implementing the invention.